INSTITUTO TECNOLÓGICO DE AERONÁUTICA

CURSO DE ENGENHARIA CIVIL-AERONÁUTICA

RELATÓRIO DE ESTÁGIO

LEICHT France

LEICHT

Paris, 22/10/2018

Nome do Aluno: Francisco Raul Lobo Rodrigues

Folha de aprovação

Relatório Final de Estágio Curricular aceito em (data) pelos abaixo assinados:

Francisco Raul Lobo Rodrigues

Jiri Vraj - Orientador/Supervisor na Empresa/Instituição

Francisco Alex Correia Monteiro - Orientador/Supervisor no ITA

Eliseu Lucena Neto - Coordenador do Curso Engenharia Civil-Aeronautica

Informações gerais

Estagiário

Nome do Aluno: Francisco Raul Lobo Rodrigues

Curso: Engenharia Civil-Aeronautica

Empresa/Departamento

LEICHT Structural engineering and specialist consulting GmbH

Orientador/Supervisor da Empresa

Jiri Vraj

Orientador/Supervisor do ITA

Francisco Alex Correia Monteiro

Período

08/01/2018 a 29/06/2018

Total de horas: 856 horas

Acknowledgements

First of all, I would like to thank my family for all the support during the internship year, I wouldn't be able to carry on without their comfort words whenever I needed. I also have to thank all the members of the LEICHT team who welcomed me warmly into the company and who have always been worried about my successful integration into the team. In particular, a big thank you to Sylvain Bernard and Jiří Vraj for their regular guidance, help and trust. I will always be grateful for everything they taught me over the last year.

Abstract

This report presents the work I did at a structural design office, specialized in the field of lightweight construction. I present the three projects in which I participated, bringing them up chronologically and according to the phase in which I was involved, by specifying specially the project descriptions and my role on each of them. This allows me to develop the issues related to the design and construction of lightweight structures, more specifically tensile membranes, as well as clamping elements, connections and aluminum profiles also frequently included in a project.

Keywords: membranes, lightweight structures, ETFE, aluminum extrusions

Synthèse du rapport en français

Le présent document a pour but de présenter mon expérience au cours de mon année de césure au sein de l'entreprise LEICHT GmbH. LEICHT GmbH est un bureau d'études à la base allemand qui a deux bureaux en Allemagne et un autre siège en France. Il s'agit d'une entreprise d'ingénierie spécialisée dans les structures légères et les structures membranaires. Le stage s'est déroulé entre Juliet de 2017 et Juin de 2018, et pendant ces mois j'ai eu l'opportunité de mettre en pratique toute la connaissance que j'avais obtenue au cours de plusieurs années d'études à l'école.

Tout au long de mon stage, j'ai travaillé sur plusieurs projets de différentes durées, la plupart impliquant des structures légères, c'est-à-dire des membranes, extrusions, câbles et connexions.

Dans les chapitres qui composent ce rapport, on présentera un regard général sur le travail suivi d'une vue d'ensemble chronologique des trois principaux projets sur lesquels j'ai travaillé, tout en notant que j'ai parfois été impliqué dans plusieurs projets parallèles. Les missions qui m'ont été assignées sur chacun d'eux seront également expliquées, suivies de chiffres représentatifs des particularités de chaque projet et de mon travail. A la fin je conclus tout cela avec un bilan personnel.

À la base ces sont trois projets : Gare de Rennes, American Dream et Riverboat. Je citerai ensuite mes taches sur chacun, ce qui est dument décrit succinctement dans le rapport.

Gare des Rennes : L'analyse et la mise en propre du model 3D. Les calculs pour la détermination des réactions, des contraintes et des déplacements des coussins ETFE effectués par modélisation par éléments finis de surface sur le logiciel Straus 7. Les calculs pour la détermination de l'accumulation d'eau sur les coussins effectués par une analyse dynamique transitoire non linéaire à partir de la forme de la feuille inférieure des coussins. La prise de la descente des charges et le calcul des profilés ALU. À la fin, tout ce qui concerne les plans de fabrication, en intégrant des outils Grasshopper au model 3D et en générant des dessins sur AutoCAD.

American Dream : modéliser, placer et découper correctement les éléments concernés (comme des extrusions, des coussins et des profilés ALU), en fonction des joints de dilatation et de la portée maximale des extrusions préalablement calculées. Le développement d'une routine

Grasshopper pour obtenir toutes les éléments demandés automatiquement, en réduisant les erreurs éventuelles et en générant la fabrication. Pour la suite, la production des plans de fabrication et le développement d’une méthode systématique pour vérifier la consistance entre les profilés fabriqués et les plans rendus.

Riverboat : le calcul des feuilles ETFE pyramidales sur Straus 7, en obtenant un modèle complet avec toutes les contraintes et réactions concernant le projet. Le calcul et la mise en place sur modele 3D des connections, des pipe, des supports, des lifelines et des câbles, tout en vérifiant les contraints maximales selon Eurocode et en évitant les possibles collisions.

En générale, l’expérience de stage long m'a apporté des connaissances culturelles et sur l'industrie de la construction, un savoir-faire en logiciel de calcul d’éléments finis et en dessin technique, ainsi qu'une expérience dans l'utilisation des codes et des méthodes de calcul.

Contents

List of Figures

Glossary

Form finding: process for the design of flexible structures whose purpose is to determine their geometry in static equilibrium.

Cutting pattern: Process consisting in cutting the membrane surfaces into flat elements resulting from the search for form in order to make them constructive, since they are often undevelopable. It allows to optimize the elements in order to minimize the loss of material.

Easy: Software from technet GmbH for form finding and cutting patterns.

Strand7 (Straus7): very complete finite element calculation software containing non-linear analyses.

Rhinoceros: a computer-aided design software developed by Robert McNeel & Associates. It is mainly used to design complex shapes.

Grasshopper: Grasshopper is a visual programming language and environment developed by David Rutten at Robert McNeel & Associates, that runs within the Rhinoceros 3D. Programs are created by dragging components onto a script, where the outputs to these components are then connected to the inputs of subsequent components.

ETFE: ethylene tetrafluoroethylene. Plastic membrane manufactured in sheet form transparent or tinted from 80 to 300µm thick with a width of 1.5m. Its properties in terms of implementation in construction make it an increasingly used material.

Introduction

Over the last century, there has been a real boost in construction and calculation resources available to the engineer. Those changes are remarkable in all the fields of engineering, but being even more special in civil and structural engineering, since they are millenary and representative sciences for the history of societies. We've been able from then on to look for smarter solutions in order to figure out their optimal geometries, acquiring more and more structurally efficient structures and opening our mindset to different horizons formerly unknowns, which is exactly the core of lightweight structures. The rising of textile membrane structures, causing the emergence of new forms and a new abstraction level from architects around the world, has pushed engineering firms to create new techniques for design, expanding even more our knowledge on that topic.

German engineering has known since then to take a step forward in this field and continues to develop its know-how. That's the context in which I decided to do my internship as a structural engineer in the German design office LEICHT, which is specialized in lightweight structures. Moreover LEICHT has a strong presence onto the national market of structures, especially in ETFE facades and roofs, which has increased the number of projects taken over by the French team year after year. After six months o work in the French office in Nantes, I joined the German team in Rosenheim for the remaining six months.

For this report, first of all, LEICHT, its organization and its particularities will be presented. Then I will talk about my work organized through three different projects and tasks, all of them mentioned one by one. Each project, being singular and requiring the creation of particular solutions, they will be all presented separately, recalling in each case the nature of the building before detailing the missions entrusted to me.

Presentation of organization and internship supervisor

1. General context

LEICHT structural engineering and specialist consulting GmbH is a German design office specialized in membrane constructions. Its field of activity is very comprehensive and focuses on a variety of innovative projects: concrete, steel and complex structures, membrane structures, tensioned structures, etc. LEICHT can be involved in construction projects at several stages: the office can be responsible for the design as it can also produce the execution and design studies manufacturing.

Born in 2007 as a result of the initiative of Lutz Schöne and Florian Weiniger, two engineers and coworkers at Covertex at the moment, LEICHT is based in Bavaria with an office in Rosenheim and another one in Munich, with a core business based on membrane structures, textiles and cable networks. A new partner, Marcel Enzweiler, joined the company in 2009, and from then on he has enabled the office to extend its field of expertise to steel and concrete structures.

Following a wish to establish itself on the French market, LEICHT France was created in 2011 headed by Sylvain Bernard, who had about ten years of experience on steel structure and textile membranes. The office is based in Nantes, although meetings and visits in Paris, as well as other big cities in national territory, are scheduled pretty often.

LEICHT's three offices adopt the open space mindset, enabling common workspaces without separations, even for managers. The atmosphere is therefore very friendly and small talks between employees are natural. The fact that the three offices are located in different cities does not prevent interaction between employees in different offices. Indeed, every employee has a professional Skype account and can work without embarrassment with colleagues in another place.

Transparency within the office is strongly encouraged through a weekly meeting called "workload planning". On Tuesdays, the further coming week is planned using a excel sheet which contains the calendar of the week with everyone's tasks. It provides an excellent overview of the hours spent on a project, besides allowing the team to discuss and manage the usage of software licenses for each project and also ensure that each person has enough work.

Besides that, every month an internal training meeting is organized for all employees in Germany. Especially it allows us to share new experiences and the know-how of each other. These meetings insert us through the work of the presenter and allows us to have an overlook at the problems, and consequently their evolutions and possible solutions, of a branch of the company other than the one on which we are working daily. The meetings are often held in the form of presentations PowerPoint but can also be a visit to interesting buildings.

2. Remarkable projects

Over the next paragraphs, some of the main projects made by LEICHT will be presented.

Example 1: Coca-Cola Beatbox Pavilion

Figure 1: Coca-Cola Beatbox Pavilion (photo: LEICHT)

One of the most remarkable projects is the Coca-Cola Pavilion, a temporary structure presented at the London Olympic Games, whose red and white facade was composed of 230 cushions of 5m² in ETFE membrane with LEDs. LEICHT not only produced the detail and manufacturing drawings, but also provided static calculations for the cushion frames and their connection to the primary structure as well as assembly assistance.

Example 2 : Soccer stadium Cuauhtémoc

Figure 2: Soccer stadium Cuauhtémoc (photo: LEICHT)

LEICHT took over the structural planning (including workshop and execution planning) of one of the world's largest single layer ETFE façades. The 51,000-seat football stadium with its single-layer and multicolored ETFE membrane facade was ranked by 40,000 readers of the periodic StadiumDB as well as by an international professional jury as one of the top 5 most beautiful football stadiums of 2015.

Example 3: Grand Stade du Havre

Figure 3: Le Grand Stade du Havre (photo: LEICHT)

The flagship project that marked the creation of LEICHT France was the new Grand Stade du Havre, for which LEICHT France carried out all the execution studies, whose 32,500 m² façade is entirely covered with a single-layer ETFE membrane tinted in different shades of blue, remaining to this day the largest area ever covered with single-layer ETFE in France.

Example 4: Les Vergers de la Plaine

Figure 4: Les Verges de la Pleine (photo: LEICHT)

Les Vergers de la Plaine is a 30,000 m² shopping center in Chambourcy. Through its park space, which connects the many supermarkets, stores and boutiques with the Carrefour shopping center, there are remarkable 12m high organic canopies that interlock like mushrooms and, covered with ETFE membranes, protect visitors from the sun and rain. LEICHT France carried out preliminary and detailed design for steel structures, workshop planning for pillars as well as the complete design of ETFE membranes from shaping to workshop planning.

3. Presentation of internship supervisor

During my internship, I had two different supervisors, one in Nantes and other in Rosenheim. I will present them both separately:

- Sylvain Bernard studied mechanical engineering at the University of Nantes, getting specialized in numerical modelling, simulation and visualization. In his position as a design engineer at the CSTB, he was in charge of carrying out studies by experimental simulation of the effects of wind on high-rise buildings. As an engineer at ACS design office (a subsidiary of the BHD group) and at BUREAU VERITAS, a worldwide control, inspection, classification and certification office, Sylvain Bernard has become an expert in metal structure and is one of the leading specialists in textile membrane structures in France.

- Florian Weininger studied structural engineering at the Technical University of Munich. In an in-depth study of statics and timber construction he became a specialist in the field of construction engineering before he expanded his expertise at Covertex with regard to membrane and film construction. In 2007 together with Lutz Schoene he founded the engineering office LEICHT. Besides his activities for LEICHT, he teaches and conducts research at the chair for the Science of Support Structures of the faculty of architecture at the University of Applied Sciences Munich.

General overview of the work

Throughout my internship, I worked on several projects for different durations, most of them involving lightweight structures, in other words, including membrane, extrusions, cables and connections.

The work teams were usually composed by two, three or four people not necessarily from the same office, depending on the budget allocated to the project and its deadline. The office also implements a system of verification by an engineer not involved to the project on the elements designed before releasing, which we used to call Quality Check or QS (from the German *Qualitätskontrolle*). Even if this approach is very time-consuming, it avoids a maximum number of errors that could have undesirable consequences and makes us maximally sure about what is meant to be set or fabricated.

During the different projects, most of my work was done either in English or in French, to write documents as well as to talk with my colleagues, and sometimes in Portuguese or even German when needed. The need to switch easily from one language to another with a very specific and technical vocabulary was a real asset of the internship.

In practice, I used to work almost all day in front of a computer. My assignments often consisted of 3D modeling, drawings and design calculations followed by calculation notes. For the graphical representation, I mostly used AutoCAD (consequently Athenas) and Rhinoceros 5.0 (consequently Grasshopper), then 6.0 after its release and installation of the licenses on the server. I acquired a good level of knowledge on Grasshopper by direct application on projects, which allowed me to produce parametric 3D models of structures or manufacturing plans for more complex geometry projects.

For the study of lightweight structures, the office generally moves back and forth between two softwares. I mostly learned to master Strand7 software, particularly adapted to membrane structures since it allows non-linear calculations. The other software is a German one called Easy, which makes possible to do a proper form finding on membranes and cable structures and to produce cutting patterns plans for the production of membranes. I did not have the opportunity to work on Easy, given the lack of available licenses for everyone (just 2 for all the offices).

Over the next sections, the three main projects on which I worked will be detailed in chronological order, while noting that I was sometimes involved in several parallel projects. The missions assigned to me on each of them will also be explained, followed by figures representative of the particularities of each project and my work.

Gare de Rennes

1. Project description

The project consists of the Rennes Station, which is meant to be a structure linking the northern and southern districts of the city with landscaped spaces. A station which about 120,000 passengers will pass by daily compared to 64,000 today with the high-speed TGV, putting the capital at 1h27 from Rennes.

Figure 5: Gare de Rennes project (photo: eurorennes.fr)

Firstly, we were commissioned by the company Gagne to carry out a design study about the cushions composing one part of the roof. Throughout the study, the contract was extended several times and we ended up taking over the whole ETFE project, including the execution drawings and cutting patterns.

2. ETFE Cushions Calculations

My first task was having a proper look on the Rhino 3D model released by the steel structure concerned office and communicate with the manager in order to check if we can extract everything we need for our calculation from their model. For that, some back and forth were needed until to the moment we received a mockup complete enough, allowing us to start generating the cushions shape from the boundaries and borders of steel structure.

Apart from that, load cases and assembly hypothesis were also discussed with Gagne. The geometric considerations and the models from other companies previously involved on the project were also discussed and taken into account.

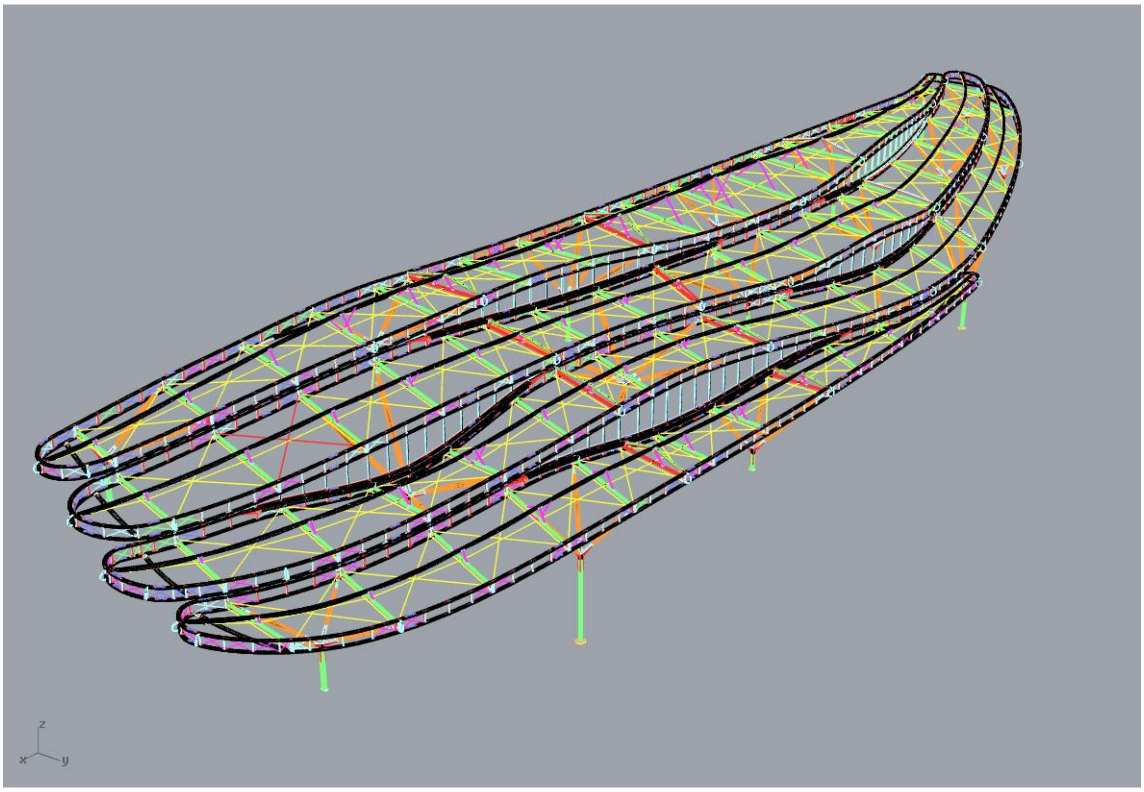

Figure 6: Gare de Rennes 3D model

Calculations for the determination of reactions, stresses and displacements of ETFE cushions were performed by surface finite element modeling on Straus 7 software. Calculations are carried out by a non-linear method integrating geometric and material non-linearity.

The calculations were performed independently for the inner and outer sheets and the results were then assembled to obtain the results of the cushions. This approach places the dimensioning of the cushions safely and is less time-consuming, especially for an exhaustive study.

The results of the calculations are given in the local reference mark of the cushion. A local reference mark is defined for each cushion.

The development of the calculations is carried out according to the following protocol:

1. Definition from the system lines of the local cushion marker from 3D-model.
2. Definition of reference arrows and strings for the form finding of inner and outer sheets in AutoCAD.
3. Meshing of the inner and outer leaves on Rhino.
4. Integration of meshes for the shape search of inner and outer leaves on Straus 7.
5. Integration of boundary conditions, material properties, load cases and load combinations on Straus 7.
6. Non-linear resolution of load case combinations on Straus 7.
7. Output of the results for each load case in an Excel file.
8. Verification of stress.

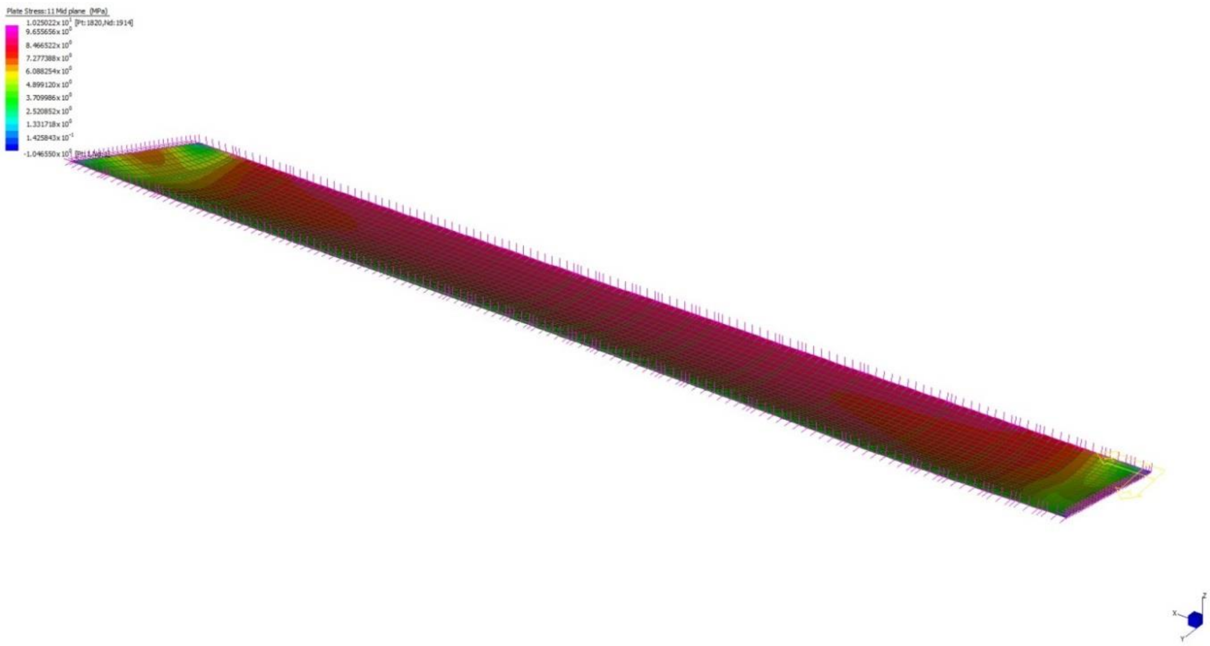

Figure 7: Stress of critical cushion - Inner layer

On the other hand, calculations for the determination of water accumulation on the cushions are carried out by a non-linear transient dynamic analysis from the form finding of the lower sheet of the cushions.

This analysis can be broken down as follows:

1. Integration of the form finding of the inner leaves in Straus 7.

2. Integration of boundary conditions, material properties, ULS snow load and additional water load potential from the cushion sewer point into Straus 7.
3. Resolution of the non-linear transient dynamic system as follows:
   - 2 seconds during which the ULS snow load and additional water load under the sewer are applied,
   - 8 seconds during which the ULS snow load is gradually removed and the additional water load under the sewer is applied,
   - 2 seconds during which the additional water charge under the sewer is applied.
4. Analysis of the results relating to the convergence and stabilization of the system.

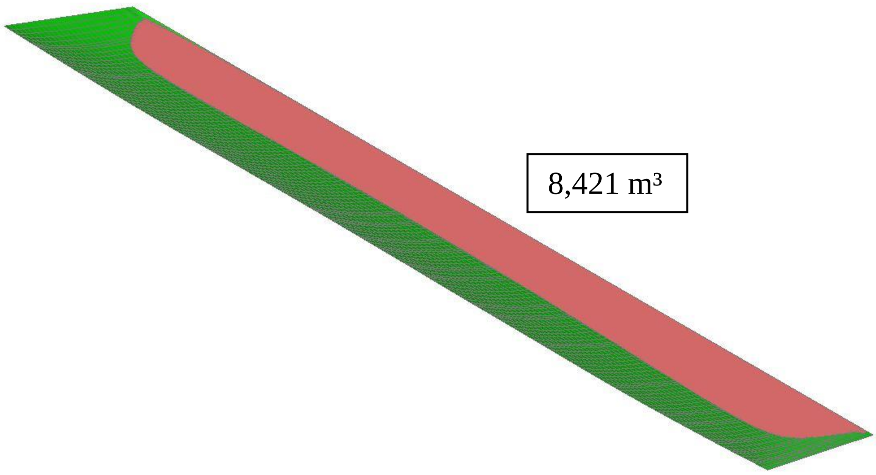

Figure 8: Water ponding of critical cushion

Taking into account the geometry and climatic loads retained for the project, several cushions studied presented a possibility of water ponding on the roof according to the best practices for justifying ETFE roofing, as shown in the picture below.

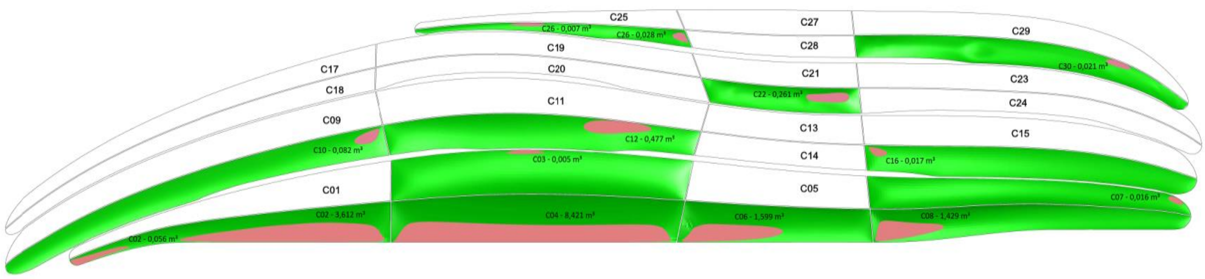

Figure 9: Water ponding overview

According to the study, we recommended some changes on the steel structure by affirming that the roof shape is compromising the ETFE cushions structurally due to water ponding. After all, the entire under part (C01 to C08 in the picture) of the structure was therefore stuck and meant to go through a new engineering solution, like upstands. This further study was still being analyzed when I left the office.

3. ALU Extrusion Calculations

Once the stress and reactions from the ETFE cushions were all set, the next step was the calculation of ALU extrusions, the profiles responsible for clamping and pre stressing the ETFE.

The base profile, the cap profile and the keders were previously chosen since the beginning of the project. It was the one of Taiyo, as shown below.

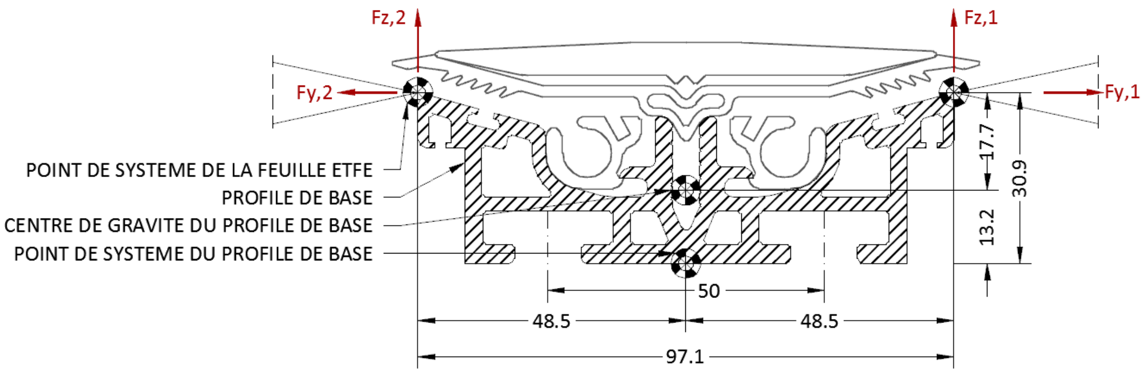

Figure 10: Taiyo extrusion

Even if the elements were established, it was necessary a verification of all the hanging elements considering the reactions from the cushions, the maximal length of extrusion, the expansion joint, and the distance between two bolts.

After discussions, we calculated the lengths from the 3D-model (maximum 3m) and decided a convenient and effective expansion joint distance. Then the worst case scenario of reactions was considered as the load case for this verification. Finally, we checked everything out using four bolts per extrusion as shown below.

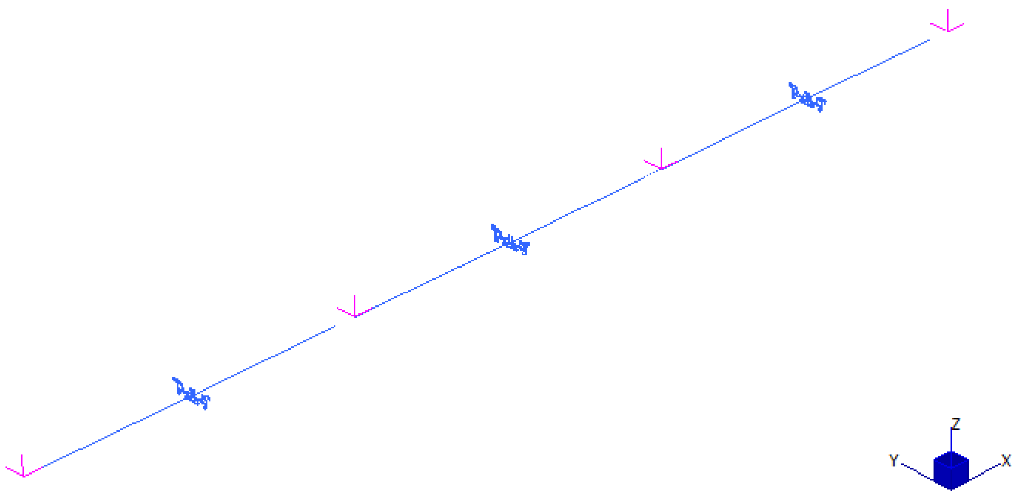

Figure 11: Extrusion model on Straus 7

4. Workshop drawings

At this phase, I took over the workshop drawings needed to the fabrication process of the extrusions and their setting up in situ. First of all, I had to develop all the extrusions on the Rhino 3D-model and export to AutoCAD. That was the moment where I started figuring out and mastering Grasshopper tools, not because was required but mostly in order to optimize my own work.

For each cushion, a numbering drawing was needed to guide the setting up and to make a reference to further welding fabrication plans.

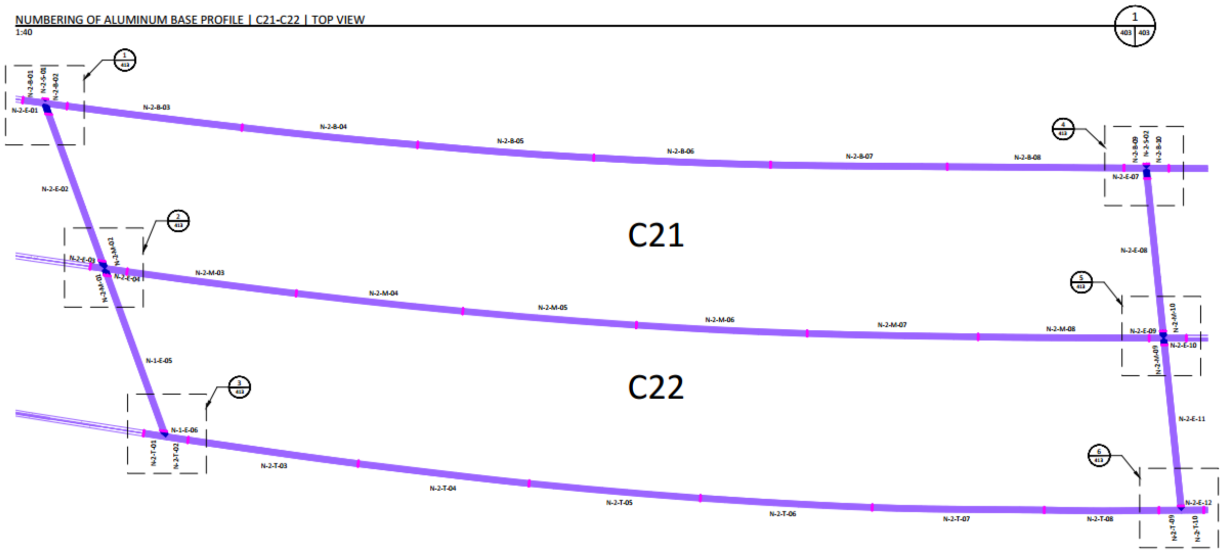

Figure 12: Numbering Top View

Welding details were also needed. Taiyo could therefore weld all the profiles on the workshop phase, avoiding the possible misundertoods with V-extrusions. Base extrusions were welded whereas cap extrusion had 2mm deviation.

The next two pictures present a welding detail drawn by me and a picture taken in situ of the same detail after the first cushion was set up. It is worth pointing out that all the drawings were made by me but passing by a proper quality check before being sent out.

Figure 13: Welding detail drawing

Figure 14: Welding detail set up

Moreover, some construction parameters of each extrusion were needed to the workshop. For that we took the 3D-model as a reference and, making use of Grasshopper, we exported to an Excel worksheet all the miter cutting information, total and mid-axis lengths and the curvature radii for each extrusion. All the output information is specified below.

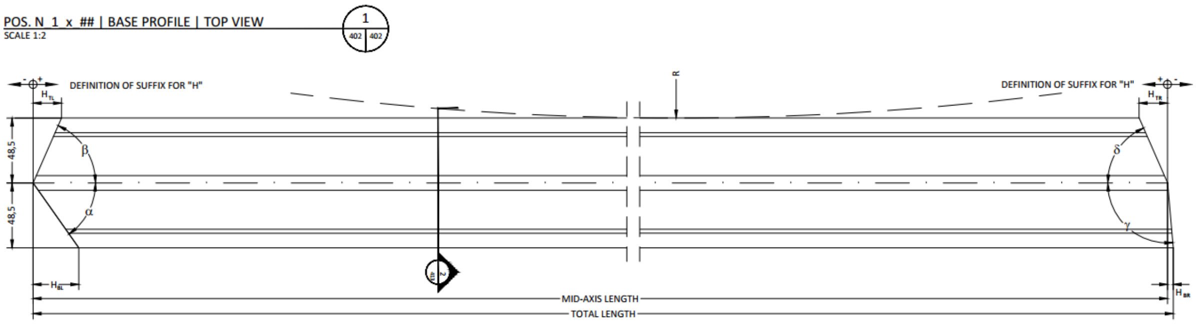

Figure 15: Workshop extrusion drawing

5. Overview and current status

Nowadays, after months and months of additional calculations and back and forth moves in order to make all the concerned parts agree, the cushions are finally being set up as presented below. Some parts of an ETFE project, like standoff calculation and air supply system, were neglected in this document to allow us to focus only in the parts on which I worked.

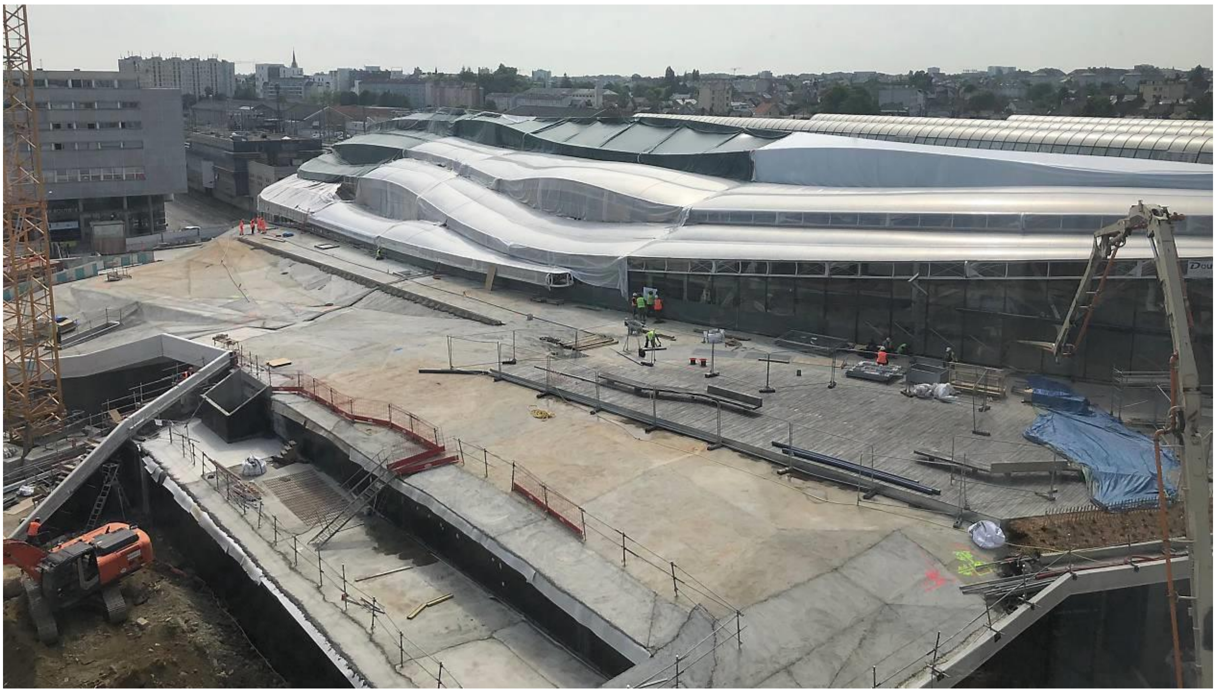

Figure 16: Current overview

An important information to point out is the fact I worked on this project for two months when I was already in Germany. Even if I was far from France, I could work normally with the French team, using Skype business and setting daily meeting to discuss about the progress and to decide the next steps. I could therefore finish my tasks and start working on German projects from then on. Nevertheless after those two months, I used to weekly pictures of the cushions and eventually photos of problems which happened during the setting up process (as shown below), so I was meant to fix it by splitting my working hours into German projects and small fixing tasks on Gare de Rennes.

Figure 17: Example of misled setting up

American Dream

1. Project description

What will be the largest shopping mall in the USA is presently under construction in Meadowlands, New Jersey. To this end the American real estate developer TripleFive is expanding an already existing shopping center into a gigantic shopping and entertainment complex: among other features it will have a water park, an indoor ski slope, an ice skating rink, a roller coaster, a Legoland and a shark aquarium. The planning for the total of four roofs of ETFE cushions and the façade of the new building extension is being taken over by LEICHT including the planning of the grid shell steel framework and the flashing.

Figure 18: American Dream (photo: LEICHT)

2. 3D-model analysis

Differently of my work on Gare de Rennes, I did not kick off since the very beginning of this project. When I started, all the static analysis were already done, so the design stress of cushions, aluminum extrusions and standoffs were all known at the moment for the four roofs concerning us. Besides that, the steel grid shell had been designed aside by another engineer at the office. So my first task was exactly gathering everything on the single roof 3D-model in order to check inconsistent elements and possibly clashes.

In the figure below, we can see an example of clash between the ETFE cushion from Easy, deformed under critical load case and 100 mm offset down, which is also known as no fly zone. According to this, the cushion has to be somehow changed, either decreasing the arrow of the pillow or decreasing the deformation when submitted to the load case by changing the thickness of the layer.

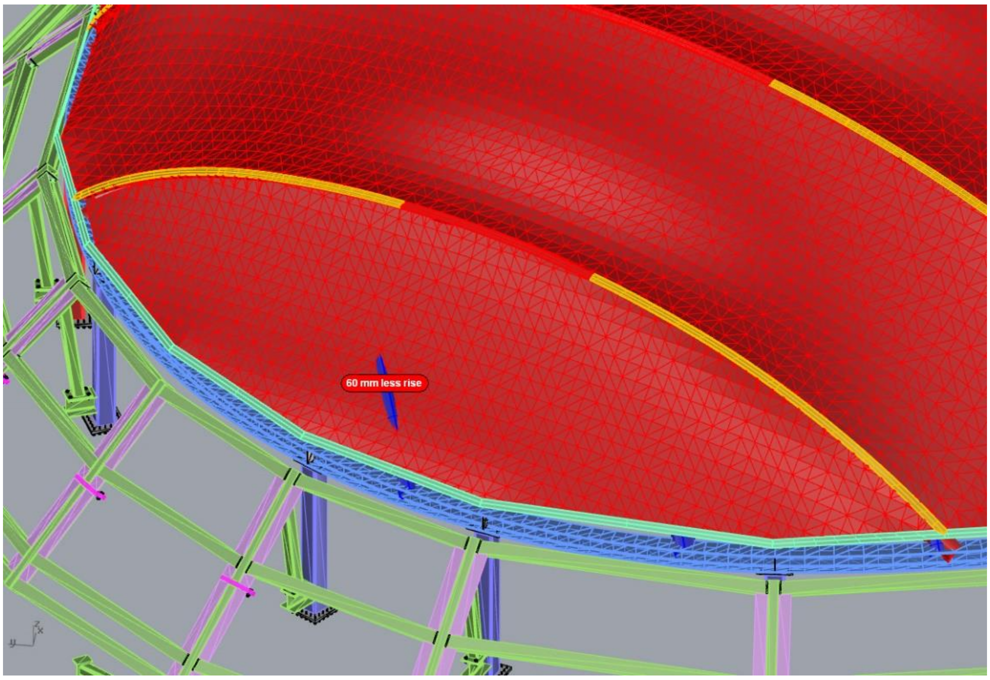

Figure 19: No Fly Zone clashing with grid shell

Furthermore, the extrusions and standoffs were required to be inserted on Rhinoceros. I was therefore in charge of modelling, placing and cutting those elements properly, according to the expansions joints and maximal span of extrusions, which had been previously calculated.

3. Workshop drawings

This section concerns to what can be considered the most important contribution that I did to LEICHT throughout one year. It was a front line of the project that, even under quality checks and eventual interventions of the project manager, I ended up leading almost by myself.

On American Dream, the company responsible for the manufacturing of extrusions is called Birdair and is headquartered in Rosenheim. As expected, every fabricator has their own way of work, each one having their particular mindset and way to proceed. For me, the main difference from Taiyo to them was the precision. The Taiyo extrusion fabricated to Gare de Rennes were a rough approach, presenting remarkable deviations from the 3D-model. So we worked starting from an assumption that the extrusions were supposed to be bent and forced on the site to fit perfectly over the steel structure. The Birdair extrusion was however an accurate representation of the 3D-model and they required that from us, including several quality checks and ways to verify that everything is properly exported and sent to workshop. It happens maybe because of the project conditions: the extrusions were fabricated in German and shipped to USA, so Birdair as much as LEICHT were afraid of sending the profiles overseas and they do not fit perfectly in the end. The mindset in this case is it’s better to sin by commission than by omission, otherwise the costs will increase exponentially (with the possibility to ship something twice).

Firstly, we defined together that every extrusion would have 6 control point (from 0 to 5), as shown in the next drawings. After that, we defined what parameters would be exported to a worksheet and submitted to the workshop process. Finally we decided the limit values for each parameter. For example, if the strong axis bending radius were less than 35m, the extrusion would not need to run through the bending machine, which makes the fabrications faster and more simplified.

The geometric parameters defined were: lengths (total, mid-axis and under ones), miter cuts, under cuts, soft axis radii of bending, hard axis radii of bending and twist, all of them being also presented in the next drawings. Besides that, we defined an orientation for each extrusion composing the roofs and I had enough autonomy to set all this and impose my opinion about the project, by participating of meetings and exchanging emails with Birdair engineers.

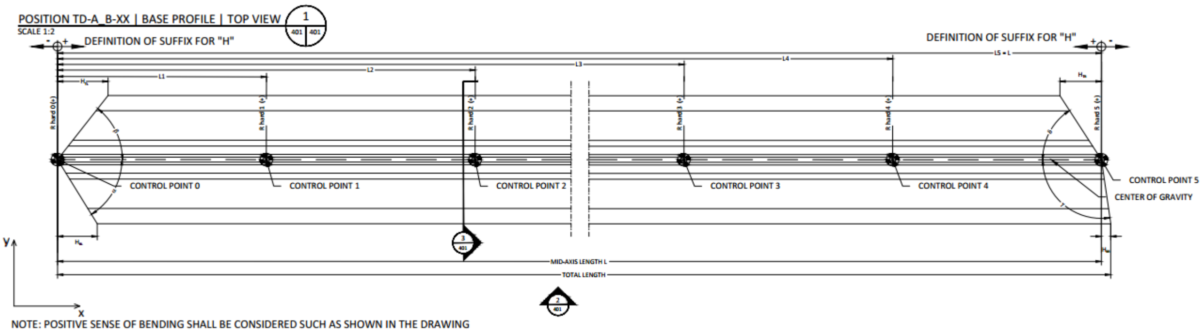

Figure 20: Base extrusion drawing - lengths, miter cuts and hard axis radii

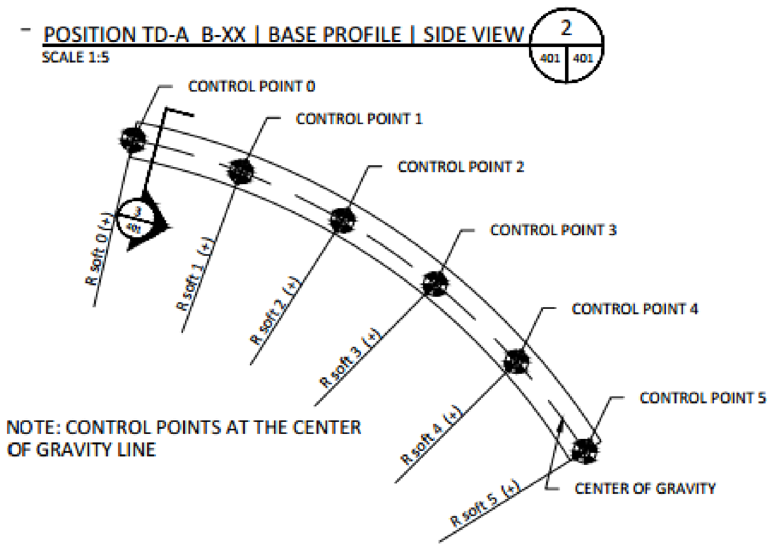

Figure 21: Base extrusion drawing - soft axis radii

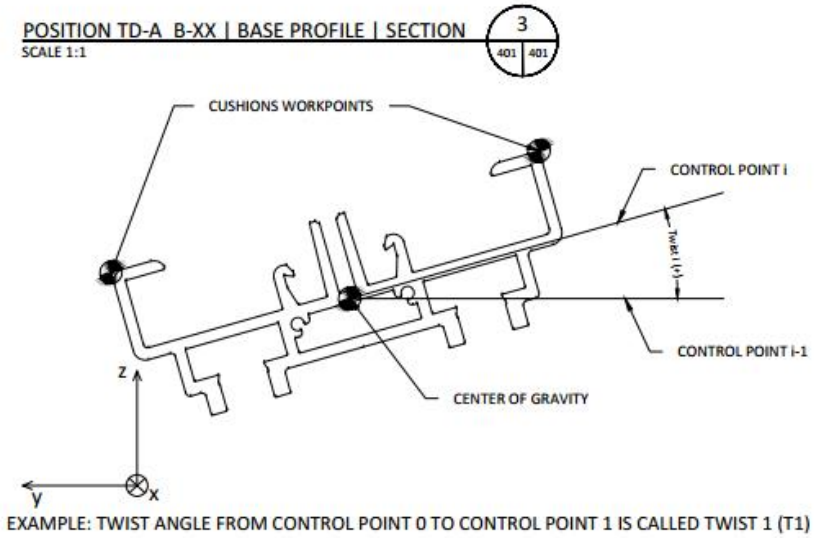

Figure 22: Base extrusion drawing - twist

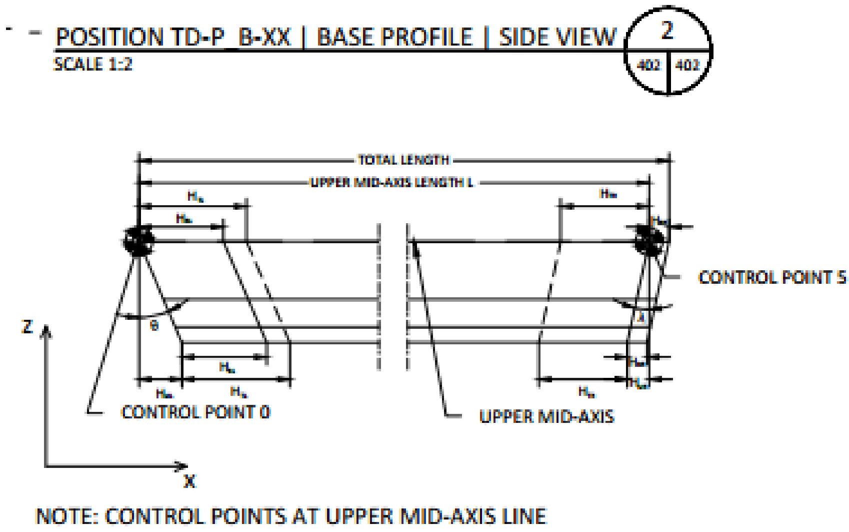

Figure 23: Base extrusion drawing - lengths and under cuts

Finally, the real challenge for me was developing a Grasshopper script to obtain all those outputs automatically, reducing eventual mistakes and generating fabrication plans as fast as possible, in order to accelerate the fabrication and accomplish the deadlines of shipping. Another task was creating an effective way to do a proper quality check after fabrication, which was also developed with Grasshopper.

I worked about two weeks full time on developing and improving the script. Using that, we were able to create one fabrication plan of an entire roof per day, which used to require more than one week previously, besides the boring mechanic work involved in exporting parameter from measures by hand. Afterwards, the company was satisfied with the result and they kept using the script on other similar projects.

Riverboat

1. Project description

The project consists of a high-rise tower located in North Carolina, USA, at the top of which is located a square pyramidal lightweight steel structure with ETFE panels forming its envelope.

The scope of the work destined to LEICHT was the design of the ETFE diamond panels and their relative extrusions and connections forming the aforementioned envelope, the design of the supporting steel structure to which the EFTE panels are connected as well as the fixation pipes bearing the whole pyramid and transmitting the reactions to the building.

Figure 24: Riverboat (photo: LEICHT)

2. ETFE foil Calculations

First of all, we worked on the design of the pyramidal ETFE foils on Straus 7, obtaining a complete model with all the stress and reactions concerning the project. The figures below show the model with the maximum reactions loads exerted by the ETFE foil onto the extrusion.

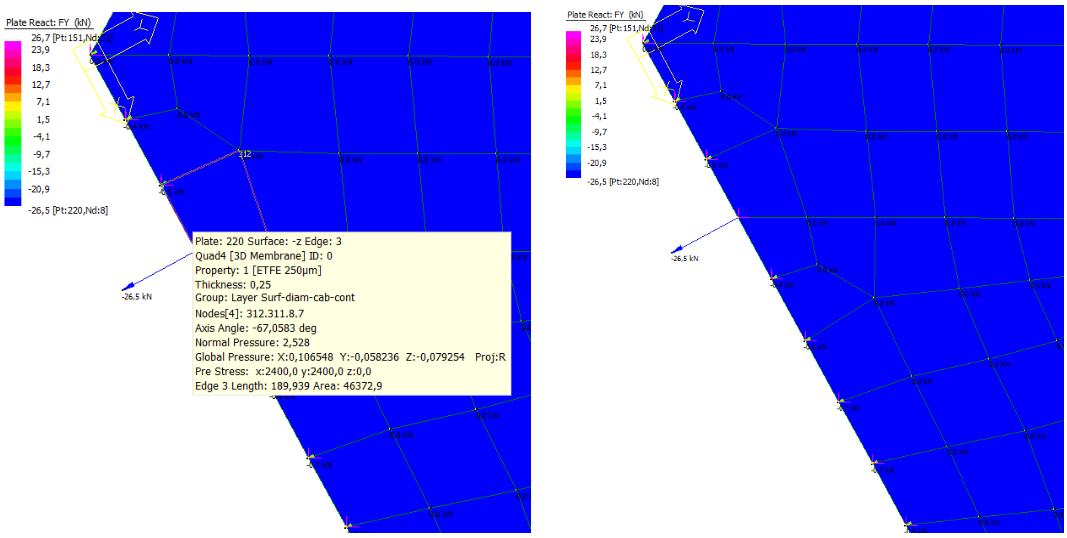

Figure 25: ETFE foil stress

Afterwards we had to translate these point loads onto linear loads, simply by dividing their average value by the average mesh edge length in the area. Once we know the stress distribution and the reactions from the envelope Straus model, we started designing the connections and extrusions.

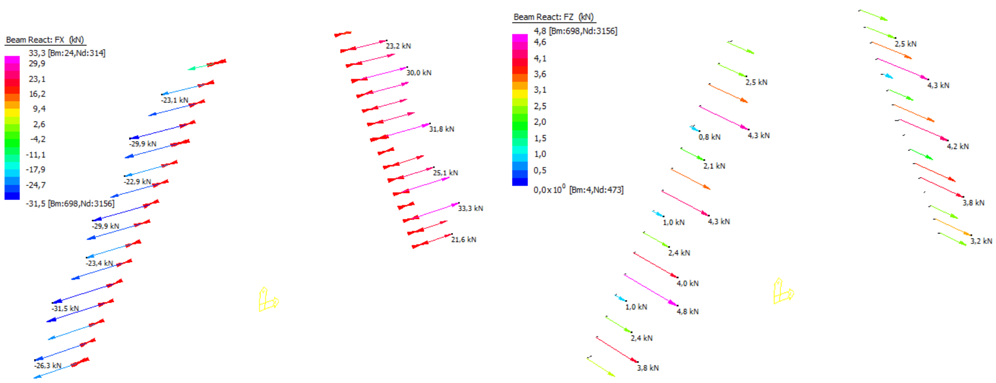

Figure 26: Envelope reactions

3. ALU Extrusion Calculations

The next figures show the extrusion profile dimensions and geometry chosen to this project and a finite element model on Straus 7 displaying the stresses distribution along the extrusion. This profile was designed according to the previously set loads, and a maximum spacing between supports of 24’’.

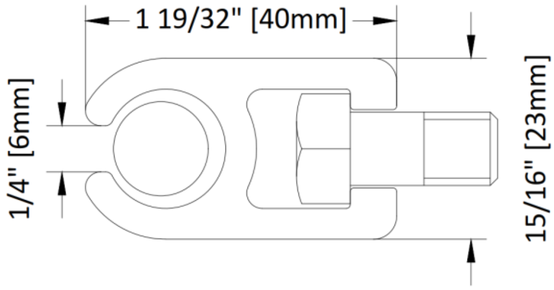

Figure 27: Cross-section extrusion, keder and bolt

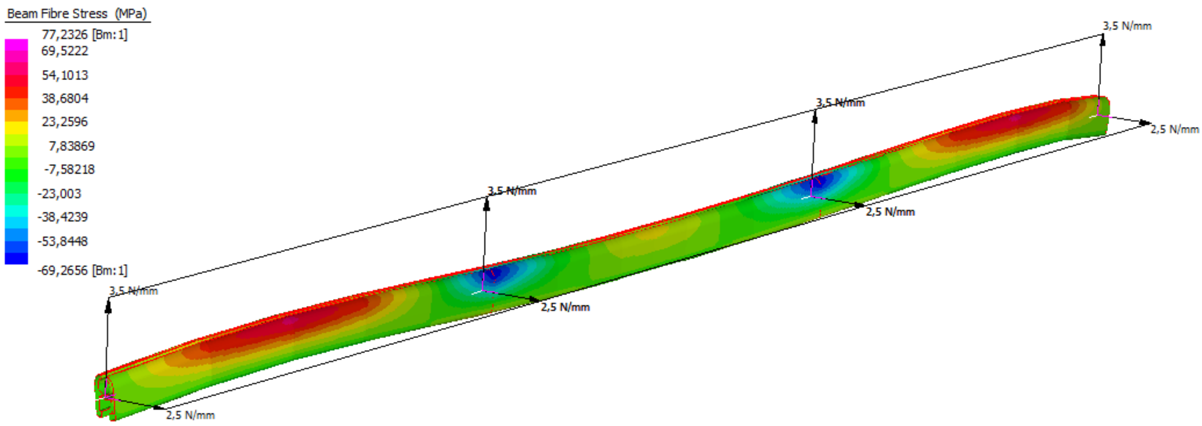

Figure 28: Extrusion Straus 7 model

At this point of my work at LEICHT, I felt already familiarized with finite elements analysis on Straus7 and how to manage the lowering loads, like the reactions of a specific element turning into a load case to another. Besides that, I was able to develop 3D-model mockups and drawings pretty well, always integrating Grasshopper for parametrize the model. That made me also responsible for integrating all the designed elements in this project on a 3D-model. So after each analyze, once the concerned extrusion/connection was validated, I carried out the model on Rhinoceros to put them all together and check collisions.

4. Steel Connections Calculations

A total of 6 different types of supports were designed. The figure below shows the location and type of the supports that are present in the project. I took over the drawings and the design of some of them, including their linear static analysis.

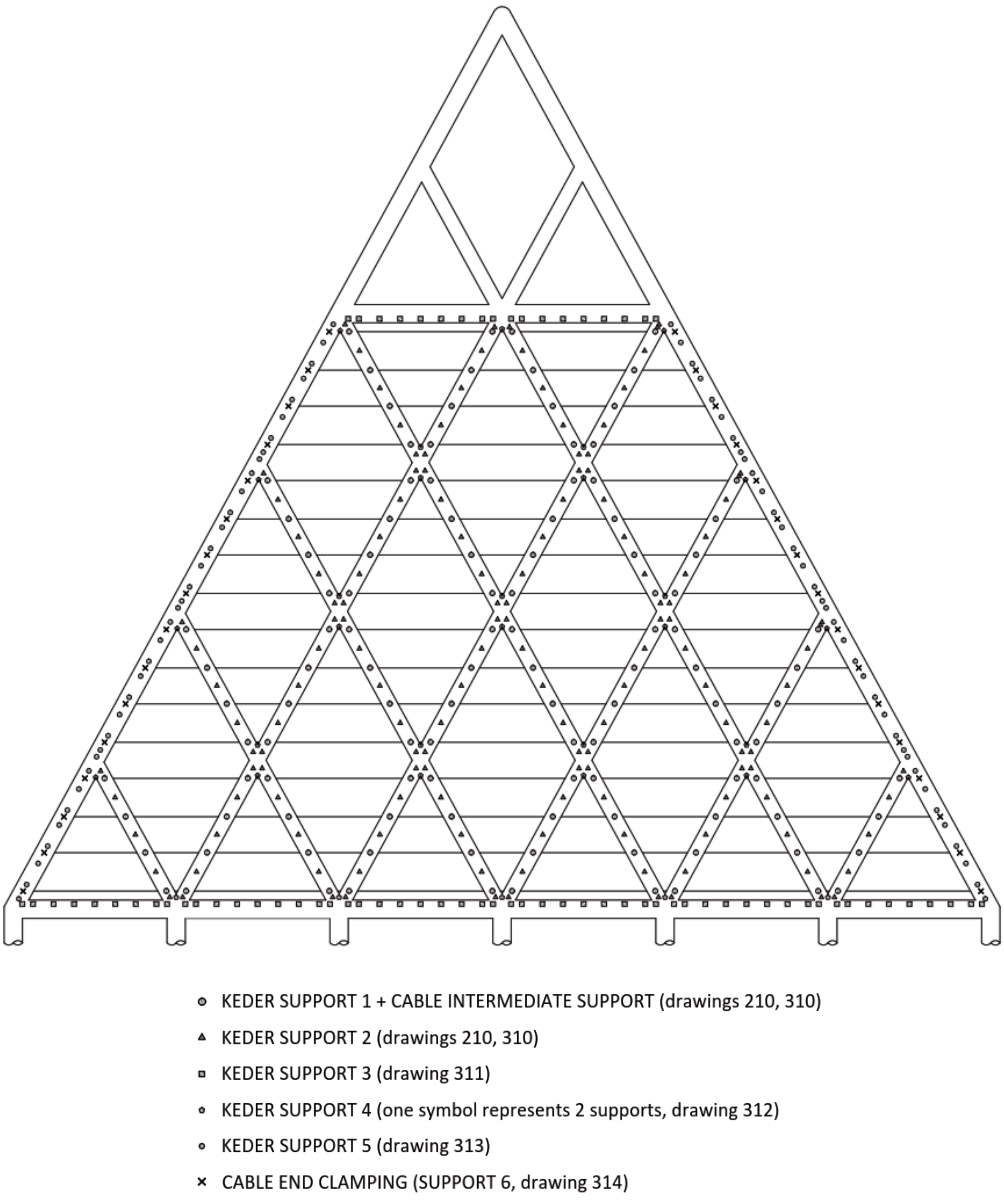

Figure 29: Supports drawing

Besides that, the pyramid is endowed with a double lifeline safety system, running both on the inside and the outside of the structure, which was also considered and calculated.

An example of support design is the support number 6, the lug onto which the end forks of the bracing cables are connected. It is made out of a laser cut 15/32'' thick plate welded onto the primary structure, as shown below.

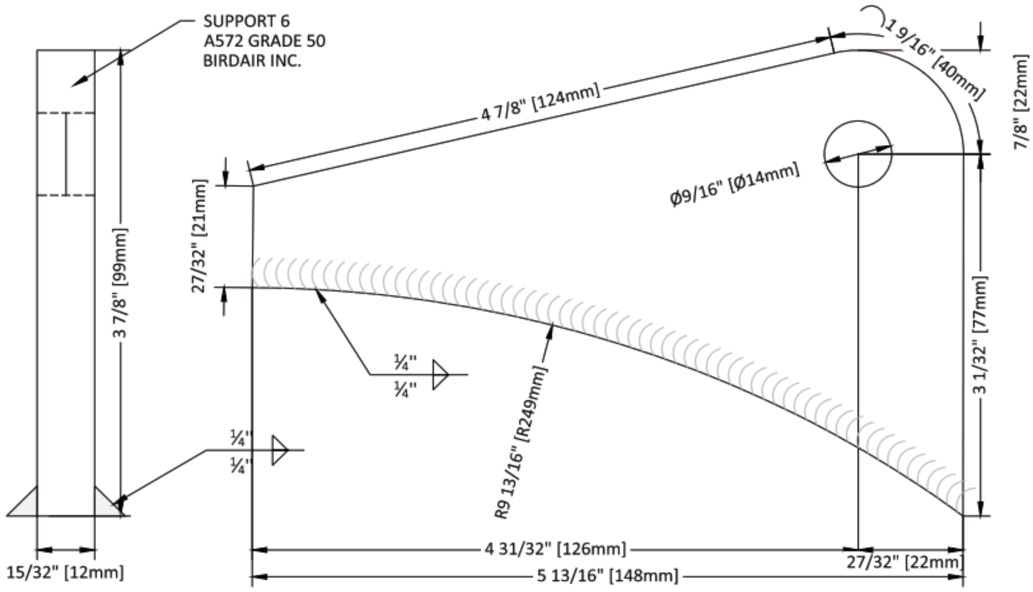

Figure 30: Drawing Support 6

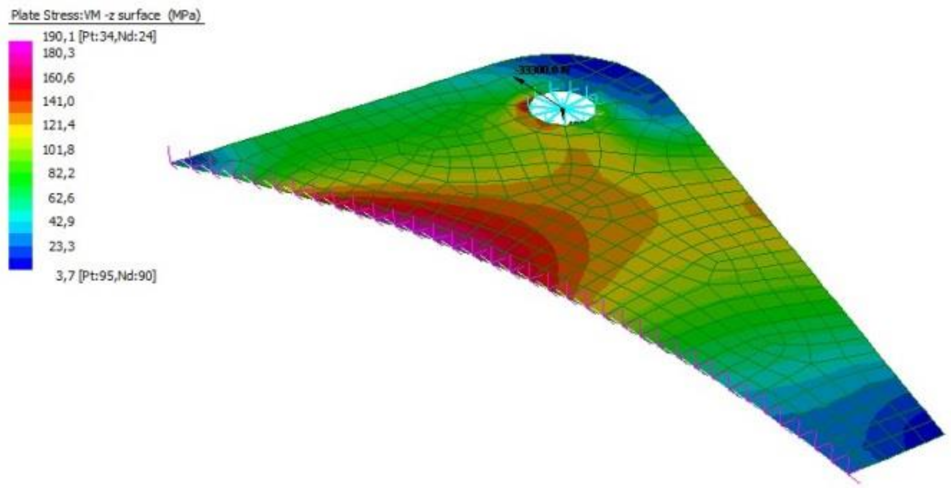

Figure 31: Stress Support 6 - Straus 7 model

Since it was already at the middle of June, that project was meant to be the last one at the company. The workflow of the project was completely different, since I was able to take some small decisions by myself and to make a progress autonomously. Also the tasks entrusted to me were escalating more and more, what made me brave enough to propose different points in the company and show them my wishes.

For the last weeks, since I had not gotten to do a cutting pattern so far, I decided to be bold and ask the manager of this project to teach me or even let me try to do at least one in the pyramid. I ended up not being really useful on that task, since I would need much more time to master the technic all the details that we need to take into account. However I could learn a lot about all the elements from ETFE behavior considered to cut and seal the patterns of each foil, as relaxation and yielding, terms which had not been aforementioned so far during my internship.

Conclusion and personal assessment

Since I was in Brazil before starting my studies overseas, I used to have my own point of view about the engineer role in a society and how I would like to be inserted in this scenario. As a future engineer, I believe that my work should go beyond technical construction, allowing me to deal with new concepts and link structural design with that of architecture. I believed at the very beginning that LEICHT was a modern company that would offer me the opportunity to do so from the different types of elements and materials, integrating architecturally innovative buildings and technically challenging structures. And the assessment after one entire year is not that different than the previous expectations.

Spending one year in a design office was, for me, the opportunity to make a link between the theoretical contents that I had seen in class and their practical application. Performing the entire internship within the same company, although in two different cities, was the perfect opportunity to go deeper through engineers work and know exactly what they do and how they proceed in certain situations. I could notice clearly that the practice is a way much different than the theory, because even though the knowledge involved in both is basically the same, the real problems consider more variables than those mentioned in the university, such as prices, partnerships, deadlines, negotiations, human resources, misled fabrication, misled setting ups, etc.

Going further in my personal point of view, the internship was a fantastic experience to grow professionally, but even more personally. When I was looking for an internship, I started hesitating between a company out of Paris but still in France in order to get used with the French market or a company abroad in order to improve my English skills and get inserted in a new culture. I ended up getting a perfect middle term between the two options. I could then enjoy the life in Nantes, an amazing city to live full of sympathetic people, as well as in Rosenheim, a cute city in the south Bavaria with cheap beer and a strong and remarkable traditional German culture. I feel really lucky for those two moments of my life. I could discover an, until then, unknown France and become someone passionate by the German culture, mindset and language.

Besides that, another personal aspect that I have to bring up is the differences between the two atmospheres and how I was able to get adapted to both of them. The French office was more focused on the market and their clients, which usually makes them obliged to manage strict deadlines, not leaving any margin to research or innovative methods, so there I was only replicating the knowledge previously established. The German office was however bigger and the bosses were open-minded to leave me creating my own scripts, calculations and models, and they were also more interested in the know-how that I was able to bring from the university to the office, always leaving me free to proceed as I prefer. My mindset is really closer to the German one, so maybe that’s why I performed better and was better scored there. In the end, they even invited me to come back and write my master thesis in Munich, and I really appreciated the relationship that set and kept there, what has made me consider the offer.

I will surely have a nostalgic view of this year: it was an opportunity to go out of the school ecosystem and have an external look at all the concepts I have learned, in France and even in Brazil. It brought me cultural knowledge on the construction industry, know-how in software calculations and technical drawing, as well as experience in the use of codes and calculation methods. More important than everything, it made me a better person with a tremendous experience and thousands of stories to tell.

Bibliography

Consulted books

- TensiNet ETFE Working Group. TensiNet European Design Guide for Tensile Structures - Appendix A5 - Design Recommendations for ETFE Foil Structures. Rogier Houtman, Tentech, 2013, 48 p.

Codes

- NF EN 1990 (/NA) 2003-03, Eurocode 0 – Bases de calcul des structures
- NF EN 1991-1-1 2004-04, Eurocode 1 – Actions générales — Poids volumiques, poids propres, charges d'exploitation des bâtiments
- NF EN 1991-1-3 (/NA) 2004-04, Eurocode 1 – Actions générales — Charges de neige
- NF EN 1991-1-4 (/NA) 2005-11, Eurocode 1 – Actions générales — Actions du vent
- NF EN 1993-1-1 (/NA) 2005-10, Eurocode 3 – Calcul des structures en acier
- NF EN 1999-1-1 (/NA) 2007-08, Eurocode 9 – Calcul des structures en aluminium

Websites

- Leichtonline [référence du 21 Septembre 2018], http://leichtonline.de/
- Eurorennes [référence du 21 Septembre 2018], http://eurorennes.fr/